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A continuous illusion of having a sixth finger

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Abstract

Our body is central to our sense of self and personal identity, yet can be manipulated in the lab surprisingly easy ways. Several multisensory illusions have shown the flexibility of the mental representation of our bodies by inducing the illusion of owning an artificial body part or having a body part with altered features. Recently, new studies showed we can embody additional body parts, such as a supernumerary finger. Newport and colleagues (2016) recently reported a novel six-finger illusion using conflicting visual and tactile signals induced with the mirror box to create the illusory perception of having a sixth finger for a brief moment. In the present study, we aimed to replicate this result and to investigate whether the experience of embodiment of a sixth finger could be prolonged for an extended duration by applying continuous visual-tactile stimulation. Results showed that a continuous illusion of having a sixth-finger can be clearly induced. This shows that the six-finger illusion does not reflect merely a momentary confusion due to conflicting multi-sensory signals, but can reflect an enduring representation of a supernumerary finger.

Our body is at the core of our sense of self and our identity as a person. It is a ubiquitous presence in our perceptual experience, in de Vignemont's words, "the fundamental core of bodily awareness is relatively permanent (…) because normally does not change" (de Vignemont, 2018, p. 11). Despite this, research over the past two decades has demonstrated remarkable flexibility of bodily experience, which can be altered using a range of surprisingly simple multisensory illusions and using virtual reality (VR) (Longo & Haggard, 2012). For example, in the rubber hand illusion, participants report experiencing a sense of body ownership over a prosthetic hand they see touched in synchrony with their actual hand (Botvinick & Cohen, 1998; Longo, Schüür, Kammers, Tsakiris, & Haggard, 2008). Analogous illusions produce ownership over faces (Sforza et al., 2010; Tajadura-Jiménez et al., 2012; Tsakiris, 2008), feet (Crea et al., 2015; Lenggenhager et al., 2015), mouths (Bono & Haggard, 2019), and full bodies (Lenggenhager et al., 2007; Petkova & Ehrsson, 2008; Slater, 2009). A range of other illusions have shown that various features of body representation can be manipulated, including the experienced size of body parts (Gandevia & Phegan, 1999; Kilteni et al., 2012; Lackner, 1988; Normand et al., 2011), body weight (Piryankova et al., 2014; Preston & Ehrsson, 2016), age (Banakou et al., 2013), ethnicity (Maister et al., 2013; Peck et al., 2013), visibility (D'Angelo et al., 2017, in press; Guterstam et al., 2013), and solidity (Senna et al., 2014). Such results show that despite the basic stability of our bodily features and our lifetime of experience with our body, our bodily experiences can be plastically altered by the features of our immediate sensory experience.

The previous examples involve situations in which the features or identity of our body or its parts are altered, but preserve the qualitative configuration of the human body. A number of recent studies, however, have gone further and shown that we can also experience extra body parts, which do not exist at all in reality. While the experience of such supernumerary body parts had been described in neurological conditions (Halligan et al., 1993; Hari et al., 1998; McGonigle et al., 2002), the finding that they can be induced in healthy participants using simple multisensory manipulations is striking. One set of studies have created the experience of having a supernumerary third arm (Ehrsson, 2009; Newport et al., 2010; Won et al., 2015). Other research has shown that participants in VR can embody an avatar with a tail, and use the tail effectively to control actions (Steptoe et al., 2013). Finally, two recent studies have created the experience of having a sixth finger on one's hand (Hoyet et al., 2016; Newport et al., 2016). Hoyet and colleagues used VR to induce the embodiment of an avatar hand with six fingers, by adding visuomotor control and feedback of the animated virtual hand and to each of the six fingers. Although they did not give instructions to control the sixth finger, participants intuitively applied strategies such as moving the ring finger to control the additional finger, feeling ownership over the sixth finger and over the whole six-fingered hand.

Newport and colleagues (2016) used the mirror box illusion (Ramachandran & Rogers-Ramachandran, 1996) to induce a somewhat similar experience of having a sixth finger, what they called the Anne Boleyn illusion. The mirror box was created in an attempt to treat patients with intractable phantom limb pain, particularly patients who felt their lost limb was clenched, with the fingernails digging into the skin (Ramachandran & Rogers-Ramachandran, 1996); watching the contralateral spared limb reflected in the mirror created the illusion of watching the lost limb and therefore, to watch it unclench, which was meant to alleviate the pain. The mirror box is often used to explore multisensory integration by manipulating visual, tactile, and proprioceptive information about the hands (e.g., Cardini & Longo, 2016; Holmes et al., 2004; Liu & Medina, 2018; Sadibolova & Longo, 2014; Romano et al., 2013). A typical mirror box setup is shown in Figure 1. The participant places their two hands on opposite sides of a mirror aligned with their body midline so that one hand is occluded while the other hand is reflected in the mirror such that it appears to be a direct view of the occluded contralateral hand. This effect allows for the dissociation of the visual information from other sensorimotor inputs, such as touch, and can create inconsistent visual and tactile signals (Cardini & Longo, 2016; Longo et al., 2012).

Using the mirror box, Newport and colleagues (2016) induced the perception of having a sixth finger by stroking the empty space near the little finger on the seen hand while the unseen hand was synchronously stroked on the little finger. The experimenter stroked the top of the five fingers of the seen hand, reflected in the mirror, followed by a stroke on an empty space next to the little finger (see the second panel of Figure 1 for a schematic of this logic). At the same time, the experimenter stroked the four fingers of the hidden hand, followed by a stroke on the lateral inner side of the little finger, suggesting both little fingers were stroked. So, when the last stroke was performed on the outer side of the hidden hand little finger, while the sixth finger on the seen hand is stroked, the touch is mapped to the sixth finger. This technique created a brief and fleeting experience of the supernumerary finger.

In the present study we aimed to replicate the results of Newport and colleagues and to investigate whether by using a different pattern of stimulation a continuous and longer-lasting experience of having a sixth finger could be induced. Experiment 1 was a direct replication of the paradigm of Newport and colleagues. In Experiment 2, we employed a new technique using twenty back-and-forth strokes to try to induce a continuous experience of the sixth finger. In both experiments, we added a follow-up procedure to the questionnaire to determine whether experiences were felt for a brief moment or for an extended period.

Methods

Participants

Twenty people ($M \pm SD$ = 30 ± 2.6 years; 15 females) participated after giving written informed consent. No exclusion criteria were applied. The study was performed in accordance to the Declaration of Helsinki and approved by the Department of Psychological Sciences Ethics Committee at Birkbeck. All participants were right-handed, as assessed by the Edinburgh Handedness Inventory (Oldfield, 1971), M = 90.3, range from 52.3 to 100.

The effects reported by Newport and colleagues (2016) were very strong. In their laboratory-based study, the smallest t-statistic comparing the illusion and control conditions in the key illusion questions was 17.5, which corresponds to an effect size of Cohen's d_z = 4.125. A power analysis using G*Power 3.1 (Faul et al., 2007) with a 2-tailed alpha of 0.05 and power of 0.95 indicated that 4 participants were required. Thus, our sample size of 20 should be well powered to replicate the illusion and to probe the duration that it lasts. Even if an effect of duration were substantially smaller than the overall illusion, we would still have reasonable power. For example, we would have greater than 0.8 power to detect an effect of Cohen's d_z = 0.7.

Procedure

We used a standard mirror box setup, similar to that used by Newport and colleagues (2016), and to other studies using this illusion to manipulate bodily experience. The participant sat at a table with a mirror (30 cm high, 40 cm wide) positioned on the table aligned with their body midline. They placed their left hand behind the mirror and their right hand in front of it. When they looked into the mirror, the reflection of their right hand thus appeared to be a direct view of their occluded left hand, as shown in Figure 1. Both hands were positioned at 24 cm from the border of the table and 20 cm from the mirror, marked by two yellow dots where they were asked to place the tip of each index finger. The participant was asked to look into the mirror at the hand throughout each trial. The left hand was hidden behind the mirror and the right hand is hereafter referred as the seen hand, although it is important to note that the right hand was not seen directly, but only its reflection in the mirror, which is perceived as the left hand due to reverse optical effect of mirrors.

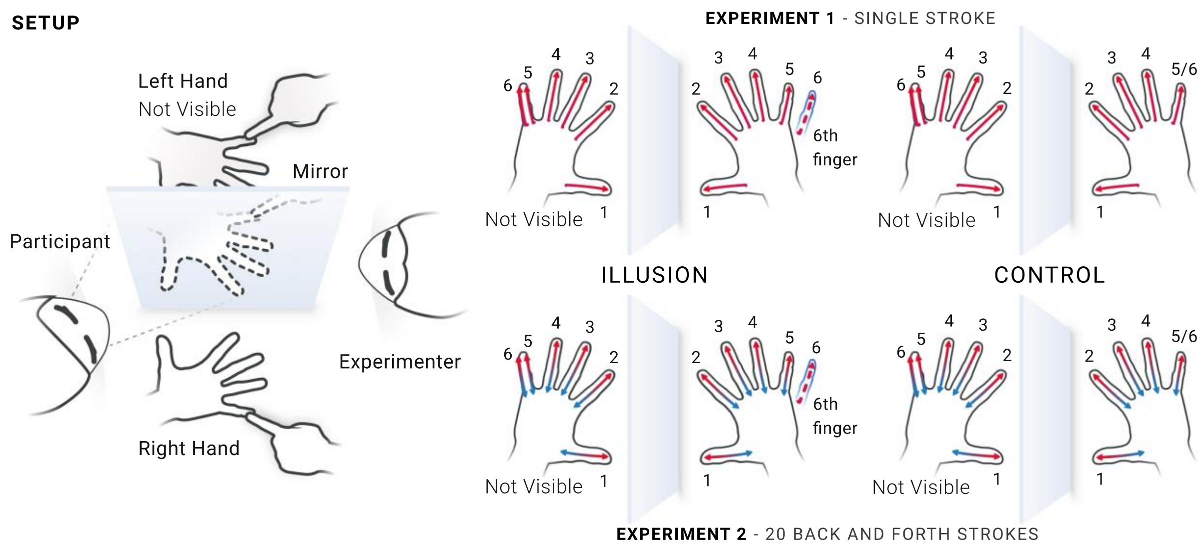

Figure 1: The experimental setup. The participant watched the reflection of their right hand on the mirror while their left hand was occluded behind the mirror. When the experimenter stroked the right hand, the participant saw that hand being stroked through the reflection on the mirror, resembling the left hand due to the mirror optical reverse effect. Each finger was stroked once, on the top of the finger of both hands synchronously, from the knuckle to the tip, starting on the thumb to the ring finger. The occluded little finger was then stroked on the inside lateral at the same time as the top of the little finger on the *seen* hand, followed by a stroke on the outer lateral of the occluded little finger synchronously to touching the empty space next to the seen little finger. In Experiment 2 the sequence is similar, but each stroke was replaced by a double back and forth stroke and the last step is performed twenty times instead of once, to assess the duration of the illusion. The control condition followed the same procedure up to the little finger, stroking the *seen* little finger once again instead of the sixth finger on the last stroke. By doing the 6th stroke on the little finger, the touch should be mapped onto the little finger, therefore no illusion should occur. The stroking sequence is numbered in the figure.

Following Newport and colleagues (2016), the logic of the six-finger illusion in Experiment 1 is shown in Figure 1 (second panel). Each finger was stroked once in sequence from the thumb to the ring finger, on the top of the finger of both hands synchronously, from the knuckle to the tip. The little finger of the occluded left hand was then stroked on the inside lateral surface at the same time as the top surface of the little finger on the seen right hand. This was followed by a stroke on the outer lateral surface of the occluded little finger at the same time as a movement of the experimenter's finger in the empty space next to the seen little finger.

In a control condition, each finger was stroked similarly to the illusion condition from the thumb to the little finger and the last stroke on the seen hand was applied on the little finger instead of the sixth finger localisation, at the same time as the outer side of the hidden little finger. The sixth stroke in the control condition was identical to the 5^{th}, preventing the illusion of a sixth finger.

In Experiment 2, the procedure was similar except that each finger was stroked four times back and forth simultaneously on each hand from the thumb to the ring finger. The occluded little finger was then stroked on the inner lateral surface at the same time as the top of little finger on the seen hand, followed by a stroke on the outer lateral of the occluded little finger synchronously to touching the empty space next to the seen little finger. The last stroke was conducted twenty times.

The same 5-item questionnaire used by Newport and colleagues (2016) was applied to assess the subjective experience of the illusion (see Figure 2 for the specific items). The order of the items was the same for all conditions and participants. Participants rated their agreement or disagreement with each item using a 7-point Likert scale from -3 ("strongly disagree") to 3 ("strongly agree"). In addition, and unlike Newport and colleagues, when participants returned a positive answer to a specific question (i.e., a score greater than 0), we followed-up by asking a further for agreement with two sub-questions probing whether the experience was felt "for a brief moment" or “for an extended period of time”. For example, if a participant gave a rating of 1 to the statement “It felt like I had six fingers on my left hand”, we then asked them to rate their agreement using the same scale to the items “It felt like I had six fingers on my left hand for a brief moment” and “It felt like I had six fingers on my left hand for an extended period of time”.

Analysis

For each questionnaire item in each experiment, we used paired t-tests to compare agreement in the illusion and control conditions. As participants rarely agreed with any of the questionnaire items in the control condition, analysis of the data for the follow-up questions was conducted comparing means in the illusion condition to 0 using one-sample t-tests. In order to ensure we had a reasonable amount of data, follow-up questions were only analysed for items for which at least half of the participants indicated agreement (i.e., a rating greater than 0) in at least one of the experimental blocks. In each case, we applied Holm-Bonferroni multiple-comparison correction to control for the fact that we conducted similar tests on multiple items.

We also compared responses between the two experiments. For overall agreement with each of the 5 questionnaire items, we conducted a 2x2 repeated-measures analysis of variance (ANOVA) with factors *condition* (illusion, control) and *duration* (single stroke, 20 strokes). For the follow-up questions, the situation is more complicated because not every participant produced data for each item in each experiment. We therefore conducted linear mixed-effects modelling (Baayen, Davidson, & Bates, 2008) using the *lme4* toolbox for R (Bates, Mächler, Bolker, & Walker, 2015) as such models do not require that data for each condition be present for each participant. For each of the three questionnaire items that at least half of the participants showed agreement with in at least one block in each experiment, we conducted separate mixed-effects models on the two follow-up questions (i.e., "brief moment" and "extended period"), modelling duration and participants as random-effects and including by-participant random intercepts and slopes. The significance of the effect of duration was assessed using model comparison (Barr et al., 2013).

Results

Experiment 1 – Single Stroke

Agreement with the questionnaire items in Experiment 1 is shown in the top left panel of Figure 2. Overall, there were clear differences between the illusion and control conditions in terms of the feeling of having six fingers, $t(19) = 5.84$, $p < 0.0001$, $d_z = 1.30$, having two little fingers, $t(19) = 4.28$, $p < 0.001$, $d_z = 0.96$, feeling touch where it is not normally felt, $t(19) = 3.47$, $p < 0.005$, $d_z = 0.78$, and feeling a touch off the body, $t(19) = 2.61$, $p < 0.02$, $d_z = 0.58$. In contrast, there was no difference between conditions in terms of feeling like there was an extra hand, $t(19) = 0.86$, $p = 0.40$, $d_z = 0.19$. This pattern of results is very similar to that reported by Newport et al. (2016), although absolute levels of agreement in the illusion condition were somewhat lower in our study.

Unlike Newport et al. (2016), when participants indicated agreement with one of these items, we also obtained follow-up ratings of whether each of these experiences was felt "for a brief moment" or "for an extended period of time". Because agreement was infrequent to any of the items in the control condition, we focused our analysis on the illusion condition, comparing mean agreement with each of the follow-up items to 0. As described above, we only analysed items for which at least half of the participants indicated agreement on at least one of the experimental blocks. Three of the items met this criterion, as shown in the top right panel of Figure 2. In each case, participants clearly agreed that each experience was felt for a brief moment, for feeling like there were six fingers on the left hand, $t(11) = 7.88$, $p < 0.0001$, $d = 2.28$, that there were two little fingers, $t(11) = 8.48$, $p < 0.0001$, $d = 2.45$, and that they felt a touch where they do not normally feel it, $t(11) = 9.53$, $p < 0.0001$, $d = 2.75$. For each of these items, there was also significant disagreement that they occurred for an extended period of time, $t(11) =$ -2.67, -6.28, and -5.68, all p's < 0.05, $d = 0.77$, 1.81, and 1.64, respectively. These results clearly show that the experience of the sixth finger lasted for only a fleeting moment.

Experiment 2 – Extended Stroking

Agreement with the questionnaire items in Experiment 2 is shown in the bottom left panel of Figure 2. As in Experiment 1, there were clear differences between the illusion and control conditions in terms of the feeling of having six fingers, $t(19) = 7.86$, $p < 0.0001$, $d_z = 1.76$, having two little fingers, $t(19) = -5.49$, $p < 0.0001$, $d_z = 1.23$, feeling touch where it is not normally felt, $t(19) = 4.14$, $p < 0.001$, $d_z = 0.93$, and feeling a touch off the body, $t(19) = 6.32$, $p < 0.0001$, $d_z = 1.41$. Unlike in Experiment 1, there was also a significant difference between conditions in the feeling of having an extra hand, $t(19) = 2.93$, $p < 0.01$, $d_z = 0.66$, although absolute agreement with this item in the illusion condition was substantially lower than all the other items.

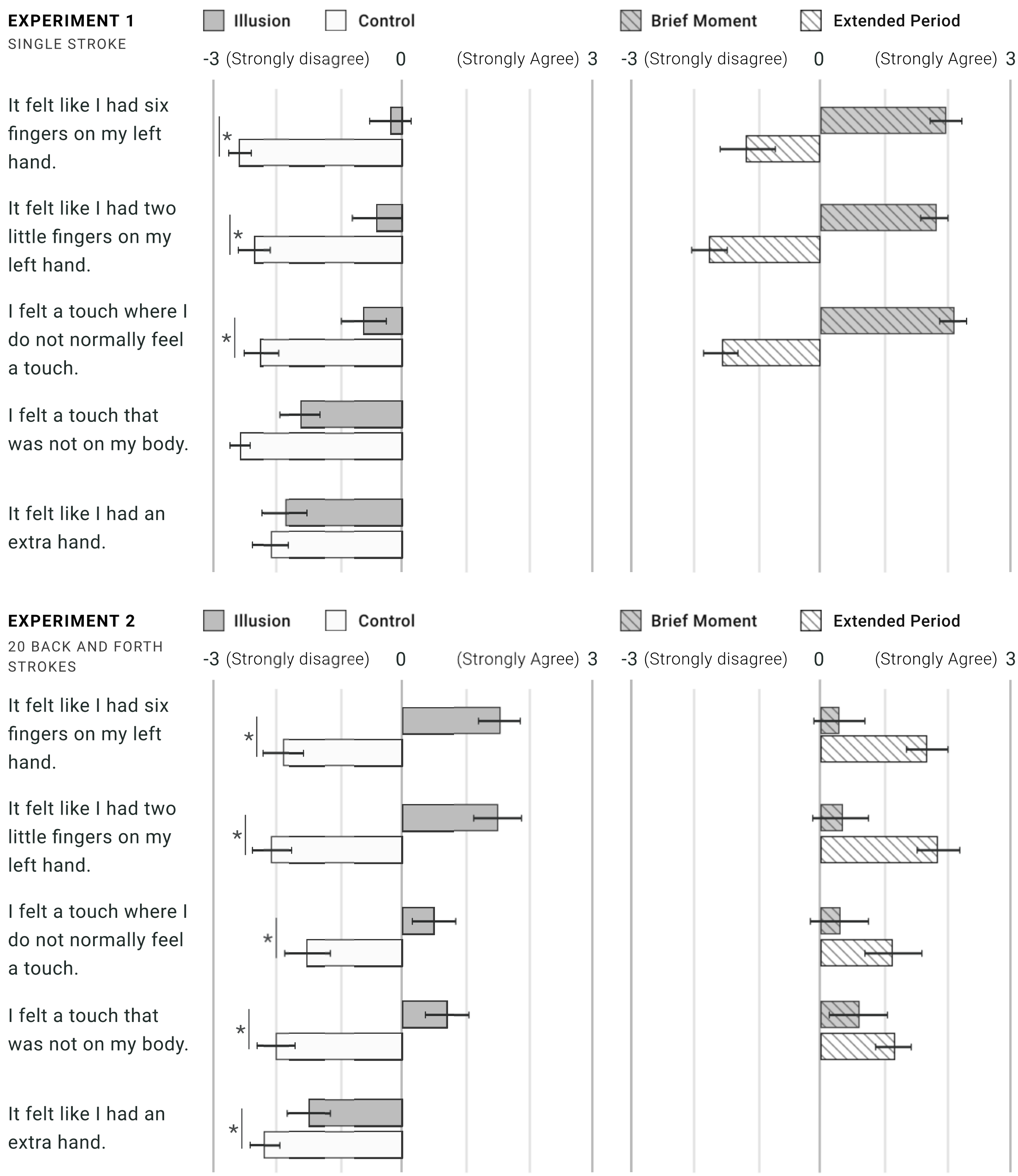

Figure 2: Mean scores for the reported experience of embodying a non-body part, using a 7-point Likert scale. Illusion and control conditions were counterbalanced, and the results averaged between the two trials of each condition. In Experiment 1, a single stroke technique was applied, similar to the Newport study, whereas in Experiment 2 we applied a double back and forth stroke, with a final step of 20 strokes on the sixth finger. Overall, the illusion of having a sixth finger was successfully induced in Experiments 1 and 2, significantly different from the control condition. There were higher scores in Experiment 2, with a main effect of illusion and experiment in inducing the illusion. When participants answered positively to

experiencing having a sixth finger or a touch outside of the body, a second question followed to assess if the illusion was felt for only a moment or for a long duration; these results are presented in the right side of the panel. Generally, participants felt a sixth finger for only a moment in experiment 1 and felt the illusion for a long duration in experiment 2.

Four of the items were agreed with by at least half the participants in at least one illusion block, as shown in the bottom right panel of Figure 2. In striking contrast to Experiment 1, participants now agreed that the experiences occurred for an extended period of time, for having six fingers, $t(18) = 5.02$, $p < 0.0001$, $d = 1.15$, having two little fingers, $t(17) = 5.41$, $p < 0.0001$, $d = 1.28$, feeling touch where it is not normally felt, $t(13) = 2.57$, $p < 0.05$, $d = 0.69$, and feeling a touch off the body, $t(13) = 4.20$, $p < 0.001$, $d = 1.12$. Again in contrast to Experiment 1, there was neither significant agreement nor disagreement about these experiences occurring for only a brief moment for any item, $t(18, 17, 13, 13) = 0.79, 0.76, 0.72$, and 1.29, $d = 0.18, 0.18, 0.19$, and 0.35, respectively. These results indicate that unlike in Experiment 1, the experience of the six-finger illusion lasted continuously for extended periods of time.

Between-Experiment Comparisons

To assess the effects of the amount of stroking, we conducted further analyses comparing the results from the two experiments. The 2x2 repeated measures ANOVA showed there was a significant effect of condition and experiment in embodying a sixth finger, in all questions except for feeling an extra hand. There was a significant interaction between condition and experiment for questionnaire items 1 and 4. Overall, condition significantly influenced the embodiment of a sixth finger, as shown in Table 1.

The embodiment of the sixth finger was also significantly influenced by experiment, denoting the effect of the type of procedure in inducing the illusion.

Table 1 Main effects of condition and experiment in inducing the six-finger illusion (2x2 Repeated Measures ANOVA)

		Q1		Q2		Q3		Q4		Q5	
	DF	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*
Condition	1, 19	60.38	**< .0001**	*55.55*	**.0001**	21.00	**.0002**	36.71	**< .0001**	6.06	**.02**
Experiment	1, 19	31.58	**< .0001**	5.26	**.03**	18.31	**.0004**	90.73	**< .0001**	0.33	.57
Condition*Experiment	1, 19	7.17	**.015**	1.52	.23	0.57	.46	10.95	**.004**	2.03	.17

Q1: It felt like I had six fingers on my left hand | Q2: It felt like I had two little fingers on my left hand | Q3: I felt a touch where I do not normally feel a touch | Q4: I felt a touch that was not on my body | Q5: It felt like I had an extra hand

To analyse the follow-up questionnaire items assessing duration, we used linear mixed-effects models with random slopes and random intercepts to assess if there was a significant difference between two experiments in terms of the duration the illusion was experienced. For each of the three questionnaire items we analysed, participants agreed more that the experience lasted “for a brief moment” in Experiment 1 and that the experience lasted “for an extended period” in Experiment 2.

For the item “It felt like I had six fingers on my left hand” participants showed more agreement that the experience lasted “for a brief moment” in Experiment 1 (M = 2.00, SE = 0.25) than Experiment 2 (M = 0.32, SE = 0.40), $\chi^2(1) = 35.36$, $p < 0.001$, but more agreement that the experience lasted “for an extended period” in Experiment 2 (M = 1.71, SE = 0.34) than for Experiment 1 (M = -1.17, SE = 0.44), $\chi^2(1) = 59.65$, $p < 0.001$.

For the questionnaire item “It felt like I had two little fingers on my left hand”, participants showed more agreement that the experience lasted “for a brief moment” in Experiment 1 (M = 1.83, SE = 0.22) than in Experiment 2 (M = 0.33, SE = 0.44), $\chi^2(1) =$ 51.55, $p < 0.001$, but more agreement that the experience lasted “for an extended period" in Experiment 2 (M = 1.89, SE = 0.35) than in Experiment 1 (M = -1.75, SE = 0.28), $\chi^2(1) = 79.64$, $p < 0.001$.

For the questionnaire item "I felt a touch where I do not normally feel a touch" participants showed more agreement that the experience lasted "for a brief moment" in Experiment 1 (M = 2.13, SE = 0.22) than Experiment 2 (M = 0.32, SE = 0.44), $\chi^2(1) = 45.80$, $p < 0.001$, but more agreement that the experience lasted "for an extended period" in Experiment 2 (M = 1.18, SE = 0.46) than Experiment 1 (M = -1.54, SE = 0.27), $\chi^2(1, 26) = 62.09$, $p < 0.001$.

Discussion

These results replicate the six-finger illusion reported recently by Newport and colleagues (2016). The manipulation of the visual and tactile cues produced the illusion of having a six finger on one's hand, with significantly different scores obtained for the illusion compared to the control condition. Participants felt the illusion for only a brief moment in experiment 1 and felt the sixth finger for a long duration in experiment 2. The twenty back and forth strokes applied in Experiment 2, which can last between 27 and 30 seconds, allowed the illusion of having a sixth finger to be maintained throughout the strokes, only fading once the experimenter stopped stroking the fingers. The illusion endures due to the continuity of the multisensory stimulation, it does not necessarily entail a lasting change in the mental representation of our hand beyond the stimulus, although such event was not investigated in this study. It may be that the changes in the mental representation of the hand linger beyond the stimulus, similarly to the findings in other studies using multisensory illusions (Newport et al., 2010; Normand et al., 2011), where temporary changes of the body representation were identified after the trials. The embodiment of a sixth finger is dependent on bottom-up inputs, showing the flexibility of the embodiment experience of a supernumerary finger relies on the online sensorial inputs and their integration into a cohesive perception of our bodies. These results show that by prolonging stroking, the experience of having a sixth finger can be experienced continuously. Interestingly, not only was the illusion not dissipated throughout the twenty back and forth strokes, it also produced a significantly stronger illusion overall. These results demonstrate that the illusion of having a sixth finger is not due merely to a fleeting moment of confusion, but can reflect an enduring experience of altered embodiment.

To continuously feel a sixth finger on one's hand is a good example of the flexibility of mental body representations. By tricking the mind into an illusory and vivid perception of having a non-body part, we can better understand the underlying mechanisms of multisensory integration, excluding models that imply a rigid mapping for the localisation of a touch in the body. Hence, the best fitting model for the localisation of a touch on a body part is a two-stage process (Longo et al., 2010) in which a touch is first mapped relatively to other locations in the primary somatosensory cortex or subcortically, disentangled from a body reference at this stage.

Second, it is mapped to a body location representation in the cortex, the superficial schema. Touch applied to individual fingers or toes are often judged as having occurred on a different digit (Manser-Smith et al., 2018), with characteristic patterns of mislocalisations between digits (Braun et al., 2005; Manser-Smith et al., 2018; Schweizer et al., 2000). Indeed, recent work shows analogous mislocalisations even between hands and feet (Badde et al., 2019). Such mislocalisations may explain how a touch on a finger can be perceptually misplaced onto the supernumerary sixth finger in the present illusion. Tactile localisation may rely on coding of location as a discrete feature rather than as a continuous location within a somatotopic map (Azañón

& Longo, 2019), in which case touch could be transferred illusorily to a representation of a novel supernumerary digit, analogous to illusory conjunction of features in vision (Treisman, 1996). A touch on a limb can be misattributed onto a different limb type, such as a touch on the hand can be perceived as had occurred in the foot, or to the other body side, only if the limb was placed at the typical side of that limb, by crossing the arms or legs (Badde et al., 2019). If the typical side of a limb plays such a relevant role in localising a touch on a limb when a categorical localisation system is in use, it helps explain the illusion of having a sixth finger on the left hand by watching an invisible sixth finger being stroked on what seems to be the left hand while the actual left hand is being touched on the little finger. If the sixth stroke is coded as a discrete feature instead of a precise external representation (Azañón & Longo, 2019), in that case, the sixth stroke can be instantly mapped onto a sixth finger, even without the previous five strokes.

The trick of touching on the inner side of the little finger of the unseen hand at the same time as the top of the little finger of the reflected hand may be irrelevant, along with all the five strokes altogether. This will distance our interpretation of the sixth finger illusion from the idea that it is the relative mapping of the touch on the fingers that is assigning the final touch onto a supernumerary finger. If a discrete categorical system for the localisation of touch is supporting the illusion of having a sixth finger, it would be interesting to investigate if the illusion would be disrupted when a system of continuous localisation in external space is elicited. A task that requires a more precise continuous touch localisation might elicit this system, as opposed to just reporting a touch (Azañón & Longo, 2019; Badde et al., 2019).

The replication of the Anne Boleyn illusion (Experiment 1) produced results similar to, but quantitatively weaker than those found by Newport and colleagues. We attribute this to differences across participants in interpreting the experience of having a sixth finger; which could also be modulated by procedural differences: Newport and colleagues ran each trial twice and preceded the experiment with five matched touches, which may have helped participants detecting the sixth stroke.

Knowing at a conceptual level that we do not have a sixth finger does not interfere with having sensations from the localisation where a sixth finger would be. This aspect is in line with studies that distinguish feeling the rubber hand is part of their body and believing it actually is. In a recent study, Tamè and colleagues (2018) investigated this dissociation in proprioceptive drift in the rubber hand illusion by giving different instructions for the subjective measures, distinguishing between feeling and believing the illusion. Results showed that while participants did feel the illusion of being touched on the rubber hand or felt that the rubber hand was their own hand, they did not believe that was the case. This distinction is important by implying that the perceptual and cognitive processing arise from two different processes in proprioceptive drift. This is not always the case, since the influence of instruction was absent in other distorted body representations, which means there was no difference between asking about feeling or believing a particular body illusion (Tamè et al., 2017).

The present results add to a growing literature showing that people are able to incorporate additional body parts into their mental representations of their body. The six-finger illusion (Newport et al., 2016) showed we easily feel and embody a sixth finger by manipulating visuo-tactile inputs using only a mirror. This illusion can also be reproduced next to the index finger as well, with no substantial differences (Newport et al., 2016), and it seems in informal testing in the lab to work as well on any finger location or position, such as on the top of the middle finger.

Our results contribute to a growing literature showing that people can be easily induced to experience rich embodiment over bodies strikingly different from their own. Recent studies suggest the mental representation of our bodies can be even more flexible than allowing for modified body parts, it also allows us to experience having novel body parts, such as owning a virtual tail (Steptoe et al., 2013), achieved or enhanced by using the first-person perspective, visuomotor synchrony and sensory feedback in VR (Won et al., 2015).

Intriguingly, while more humans have five fingers on each hand, there are several documented cases of families with members having six fingers on their hands, (eg. Carlisle, 1813; Richieri-Costa et al., 1990). Often, however, the supernumerary finger is removed at birth since they are judged as a troublesome anomaly (McCarroll, 2000), and the neuromechanics and functionality of polydactyly hands, a congenital physical anomaly of hands with more than five fingers, had not been investigated until very recently. Mehring and colleagues (2019) investigated two polydactyl individuals with six-fingered hands. Remarkably, these individuals were able to use this supernumerary finger in highly-skilled ways, allowing them to perform types of actions impossible for five-fingered individuals. Measurement of somatotopic maps in somatosensory cortex showed that these people had a distinct representation of the extra finger. These results demonstrate that the human brain is perfectly capable of integrating non-standard body parts into mental body representations and using them to control the body part effectively. The individuals studied by Mehring and colleagues, however, have had a lifetime of experience with their sixth finger, and their nervous system had developed in its presence. Our results show that even without a lifetime of such experience, five-fingered participants can be easily induced to experience an enduring sixth-finger on their hand.

Family members with supernumerary limbs that have greater manipulation ability are a compelling case in the use of additional body parts, showing that the nervous system can develop to integrate an additional finger well-coordinated with the other fingers, without mobility or control deficits, becoming a useful asset (Mehring et al., 2019). More striking, however, is the flexibility of the body mental representation over immediate time-scales, without requiring a developing and adapting process over time. Healthy adult participants can feel that a six finger is part of their body in a few moments, by looking at their reflected hand on a mirror, being touched in a certain sequence (Newport et al., 2016). Here, we showed that this illusion of embodying a sixth finger can be maintained over an extended period of time, suggesting that our self-representation is prepared to incorporate additional body parts. Studies in VR show that we perform better with extra virtual body parts (Kilteni et al., 2012; Steptoe et al., 2013; Won et al., 2015), and choose to use novel body parts if they are of benefit to the task, learning in a fast pace to control more degrees of freedom.

Our procedure in Experiment 2 allowed the experience of having a sixth finger to be extended over a prolonged period of time. This is important in showing that the illusion of having an extra finger is not a result of a momentary confusion that is quickly resolved by the perceptual system, but can be a stable and ongoing experience. This seems to point that the localisation of touch is not being modelled by high-level inputs and are rather processed at a low-level. It also indicates that our perceptual system seems to be prepared to embody additional body parts, even though there is not a mental representation for a sixth finger in participants with five-fingered hands. It may be that as long as we have sensorial information about a limb positioned in accordance with the stereotypical limb position, we are able to embody it. Further research is necessary to identify whether a touch can be misattributed to non-body parts with varied shapes or if they need to resemble the human body configuration.

A continuous sixth finger illusion also opens the possibility of using this illusion to explore the plasticity of mental body representations in a variety of ways. Having a tactile illusion of a supernumerary finger that can be extended for potentially arbitrary durations is a practical and simple method to serve as a base condition to investigate somatosensory perception using illusion enhancement or disruption paradigms.

The illusion of embodying a virtual sixth finger was also studied, by brushing a real finger at the same time as the virtual sixth digit, positioned previous to the little finger (Hoyet et al., 2016), however the illusion relies on a confusion between the ring finger and the virtual sixth finger rather than an additional finger, requiring that the fingers proximal to the additional finger are not touched before the sixth finger. In contrast, with the six-finger illusion here described, a full six-fingered hand can receive tactile feedback and the stimulus to the sixth finger can be manipulated without disruption. This new technique can be reproduced in VR, expanding the research possibilities of non-body parts with elicited illusory tactile sensations remaining for a long period of time.

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